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Evaporation Memorandum No 49a

Empirical factors to relate Penman (1948) potential evaporation (E_{tP}) to potential transpiration (E_t) and potential evapotranspiration (E) obtained from a modified combination equation and from rainfall data.

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1. Introduction

The equation for E_t differs from that for E_{tP} as follows:

(1) $\frac{\Delta}{\Delta + (1 + r_{sdn}/r_a)\gamma}$ replaces $\frac{\Delta}{\Delta + \gamma}$

(2) $\frac{m\gamma}{\Delta + (1 + r_{sdn}/r_a)\gamma}$ replaces $\frac{\gamma}{\Delta + \gamma}$

(3) A net soil heat flux term, G, is included in calculating the energy balance for E_t

(4) The estimated net long-wave radiation is adjusted when calculating the energy balance for E_t

(Δ, γ and z/z_o have their conventional meanings, r_{sdn} (dry vegetation minimum) and r_a are the bulk stomatal and aerodynamic resistances, respectively and m is a catchment aerodynamic roughness parameter following Thom and Oliver (1977)).

From the above it is clear that there is no means of obtaining E_t directly from E_{tP} by calculation. When it is necessary to compare E_{tP} with E_t and it is either highly inconvenient or even impossible to calculate E_t from the original meteorological data a means of approximating E_t from E_{tP} is required. E is calculated from E_t and rainfall data.

2. Empirical relationships between E_{tP} and E_t and between E_{tP} and E

Wales-Smith (1979) obtained the following, empirical factors from seven years (1964-70) of data from Kew Observatory.

	J	F	M	A	M	J	J	A	S	O	N	D	z/z_o	m
E_{t100}/E_{tP}	2.72	1.49	1.29	1.15	1.05	1.09	1.11	1.15	1.28	1.70	2.64	4.06	100	2.5
E_{t200}/E_{tP}	2.22	1.29	1.13	1.00	0.96	0.98	1.01	1.04	1.15	1.44	2.21	3.32	200	1.9
E_{t400}/E_{tP}	1.83	1.11	1.00	0.92	0.89	0.91	0.93	0.97	1.05	1.29	1.88	2.73	400	1.5
E_{400}/E_{tP}	2.07	1.18	1.00	0.92	0.88	0.90	0.93	0.98	1.13	1.35	1.87	3.12	400	1.5
E_{100}/E_{tP}	2.59	1.43	1.31	1.22	1.10	1.06	1.10	1.21	1.34	1.78	2.52	3.53	100	2.5

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3. Tests of empirical relationships

The first question to be answered is how well these factors reflect average conditions at Kew.

Average duration of bright sunshine and average air temperature are effective labels of evaporativity. (The latter variable (temperature) is also a useful indication of average vapour pressure (see eg Wales-Smith, (1973)). Monthly averages of duration of bright sunshine and of air temperature, at Kew, for the period 1964-70 are compared with those for the standard climatological period 1931-60 (Meteorological Office, 1972) in Figure 1. It can be seem that the 7-year period is typical of the 30-year period. It is assumed that 1964-70 monthly averages of E_{tP} and $E_{t_{100}}$ (and hence of E_{100}) reflect average conditions at Kew. (Table 1)

A second test was made by using the empirical factors to estimate E_{t_∞} and E_{100} from E_{tP} for the year 1976 in which, an extreme drought was followed by abundant rainfall. Values of estimated and calculated E_{t_∞} and E_{100} are compared in Figures 2 and 3. In each figure the 1:1 lines and $\pm$ 10% lines have been inserted and the months are numbered from 1 to 12. Ticks (✓) have been added to show, for any month, whether E_{t_∞} or E_{100} was the better estimated; the equality sign (=) appears against points for November. This simple comparison made in a highly unusual year shows that useful estimates of E_{t_∞} and E_{100} were obtained.

In due course a large quantity of values of E_{tP}, $E_{t_{100}}$ and E_{100} will be available on a country-wide basis as a further check on the stability and usefulness of the approximate method.

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Thom, A S and Oliver, H R (1977) On Penman's equation for estimating regional evaporation. Q.J.Roy.Met.Soc. 103, pp 345-347.

Wales-Smith, B G (1979) A combination equation for potential transpiration and the evaporation from wet surfaces. Unpublished. Meteorological Office Library.

Wales-Smith B G (1973) Evaporation in the London area from 1698 to 1970. Met.Mag.,Lond., 102, pp 281-291.

Meteorological Office (1972) Tables of temperature, relative humidity, precipitation and sunshine for the world, Pt 111, HMSO, Lond.

Table 1. Values of E_{t100} and E_{100} estimated from E_{tp} at Kew in 1976 compared with calculated E_{t100} and E_{100}

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
E_{t100}	32·7	19·3	48·3	73·9	110·1	147·0	164·5	133·8	65·3	33·8	20·0	10·6	
E_{tp}	14·6	13·7	37·7	62·5	95·8	123·8	131·3	102·5	47·1	20·7	3·8	−2·5	
$\overline{(E_{t100}/E_{tp})}$	2·72	1·49	1·29	1·15	1·05	1·09	1·11	1·15	1·28	1·70	2·64	4·06	
$E_{tp}\,\overline{(E_{t100}/E_{tp})}$	39·7	20·4	48·6	71·9	100·6	134·9	145·7	117·9	60·3	35·2	10·0	/	
E_{100}	34·3	27·0	47·5	72·8	113·7	136·2	158·1	130·9	72·2	38·3	21·8	9·7	
E_{tp}	14·6	13·7	37·7	62·5	95·8	123·8	131·3	102·5	47·1	20·7	3·8	−2·5	
$\overrightarrow{(E_{100}/E_{tp})}$	2·59	1·43	1·31	1·22	1·10	1·06	1·10	1·21	1·34	1·78	2·52	3·53	
$E_{tp}\,\overrightarrow{(E_{100}/E_{tp})}$	37·8	19·6	49·4	76·3	105·4	131·2	144·4	124·0	63·1	36·9	9·6	/	

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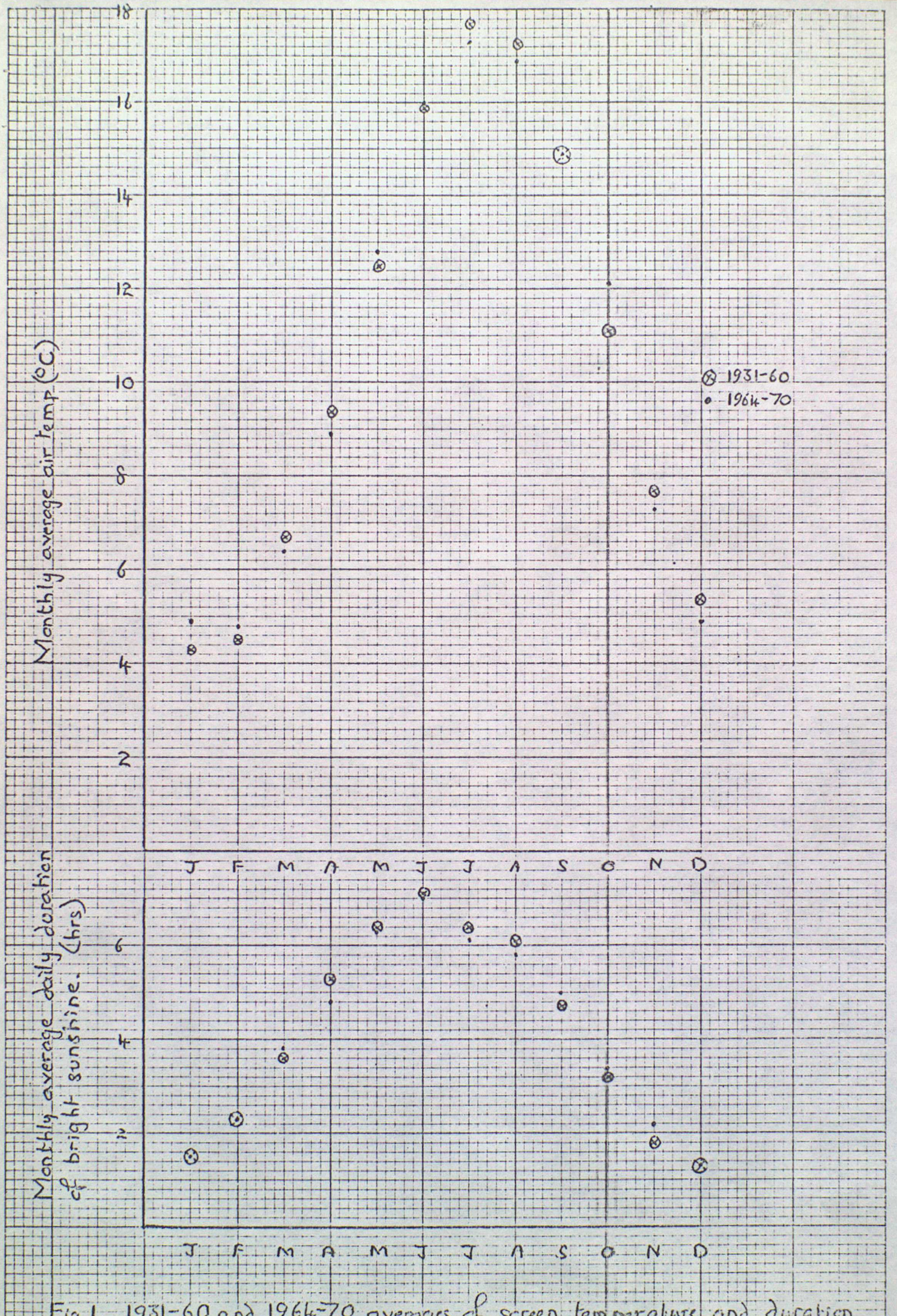

Fig. 1. 1931-60 and 1964-70 averages of screen temperature and duration of bright sunshine at Kew.

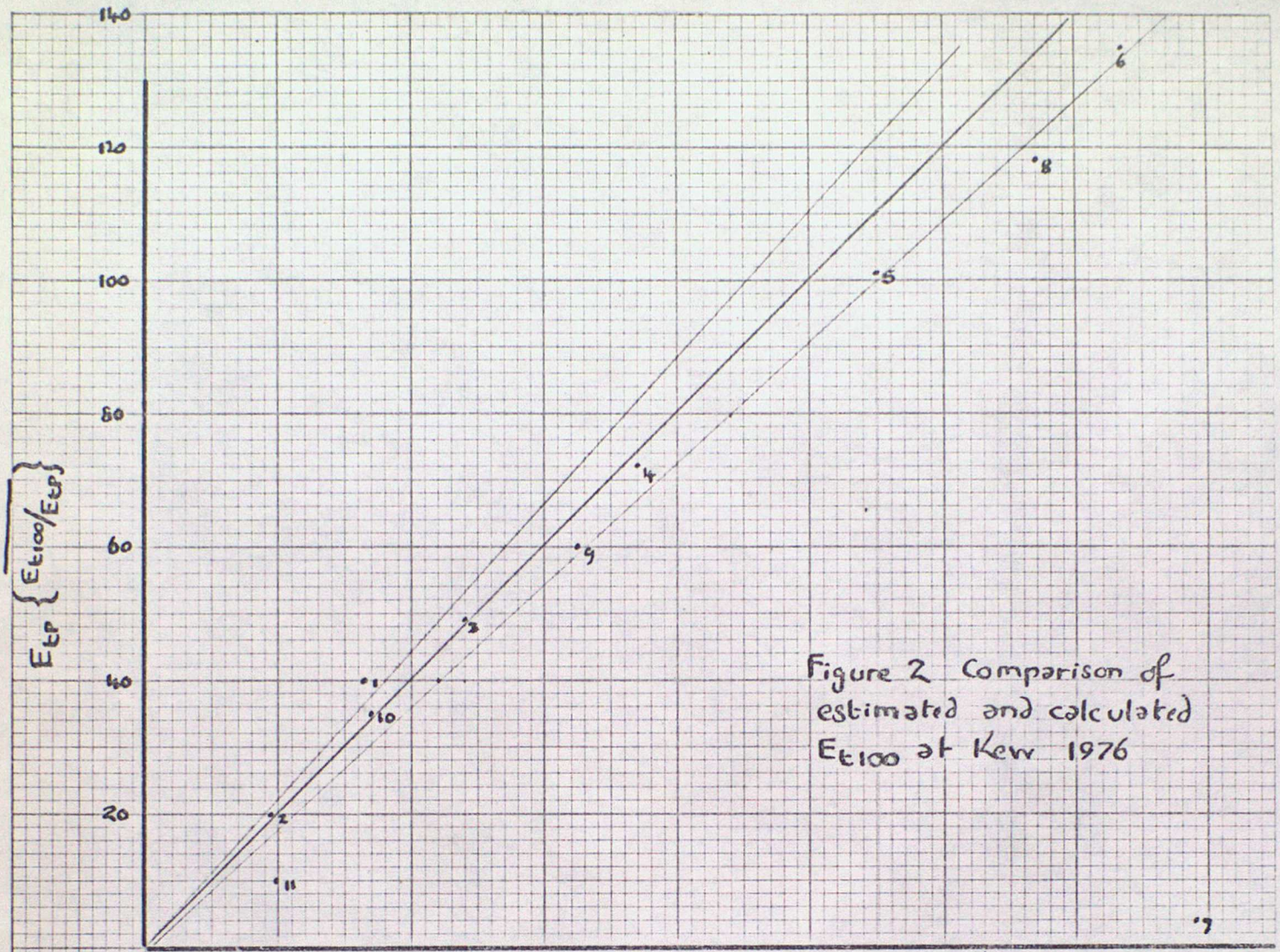

Figure 2 Comparison of estimated and calculated E_{t100} at Kew 1976

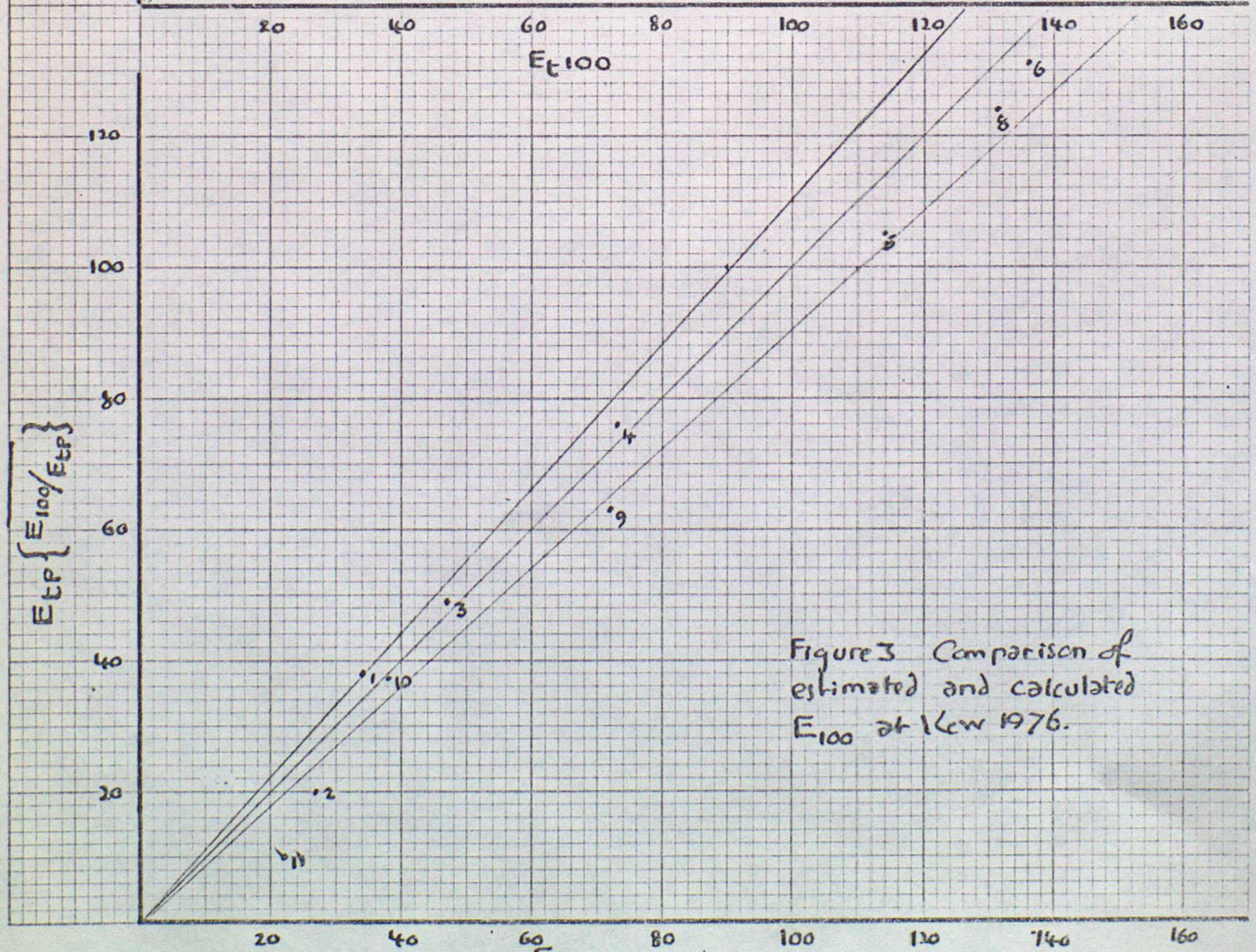

Figure 3 Comparison of estimated and calculated E_{100} at Kew 1976.